Dredger Cuttertooth Manipulator

The present invention relates to a dredger cuttertooth manipulator.

A dredger cutterhead is used to extract material from, for example, the seabed. The cutterhead is mounted at the end of a cutterladder which extends from the hull of a dredger ship. The cutterhead is rotated so that it drills or grinds along the seabed. The cutterhead is provided with arms. It has teeth mounted on leading edges of the arms. Openings between the arms form vents (or channels) for the extraction of seabed material via the cutterhead. Material from the seabed can therefore be sucked up through the openings between the arms, along the cutterladder to the dredger ship, for removal from the seabed, much like a large vacuum cleaner.

Dredger ships are often very large. For example, some have cutterheads having a weight of about 30 tonnes (30, 000kg). The cutterhead may have an outer diameter of about 3.5 meters and its height or length may be about 2.3 meters. Six spiral arms may be provided on the cutterhead, each being edged with perhaps ten teeth. This would provide a total of sixty teeth for the cutterhead. Each tooth alone weighs perhaps 20kg.

In use, the teeth engage or dig into the material on the seabed to break it apart or to loosen it. Eventually, however, the teeth will wear out. Accordingly, it is necessary, regularly, to replace the worn teeth. In order to replace the worn teeth, the dredging operation needs to be stopped and the cutterladder needs to be raised from the seabed up to a cutterplatform at the rear of the dredger ship. The cutterplatform is clear of the water so that the tooth change operation can be carried out by personnel on the ship. Worn or broken teeth are then removed from the leading edges of the arms by the personnel on the ship. Once the broken or worn teeth have been replaced, the cutterladder can be returned to the seabed. Dredging can then continue. Figures 9 and 10 show personnel changing a tooth on a cutterhead.

When dredging hard rock, typically six hundred teeth need to be replaced per day. It takes approximately 30 seconds to change each tooth. Perhaps three people are required to change a tooth. Further, the hoisting and lowering of the cutter ladder takes about five

minutes in each direction. Further, during each tooth change operation, about 20 to 30 teeth are replaced. Accordingly, the tooth change operation takes a considerable amount of real and personnel time. Further, the size of the teeth are limited by the capabilities of the individual who handles the old and new teeth. Health and safety requirements in some countries actually limit the weight of each tooth to 20kg. Further the cutterhead, being so heavy, is dangerous. Yet further, the method of removal can be dangerous. For example, heavy tools such as sledgehammers are used when manually removing and replacing the teeth. Safety, therefore, needs to be taken into consideration whenever personnel are working near or on the cutterhead or teeth. Accordingly, it would be desirable to provide a new system for a cutterhead of a dredger that will minimise equipment down times and personnel requirements, and also which will allow larger teeth to be used – a larger tooth will enable larger cutterheads to be designed and therefore faster dredging. Larger teeth will also be more durable and therefore they would need to be changed less frequently.

A system proposed in the art is to replace the entire cutterhead upon each hoisting and lowering of the cutterladder. However, the cost of providing multiple cutterheads is prohibitive; each cutterhead not only weighs approximately 30 tonnes, so involves a lot of raw materials, but is also a precisely manufactured item, having close tolerance requirements for the positions for the teeth and the tooth attachment mechanisms. They therefore are expensive to produce. Further, due to the weight of the cutterhead, replacing the cutterhead is a time consuming and dangerous process itself. Yet further the heavy weight of the cutterhead requires a very substantial piece of equipment to be installed on the ship for replacing the cutterhead. The equipment, therefore, proved to be unsuccessful. An improved and more cost efficient system is therefore required.

The present invention provides a dredger cuttertooth manipulator comprising at least one robotic tooth handler, the manipulator comprising means for:

1. removing a tooth from a dredger cutterhead; and
2. replacing the removed tooth with a new tooth.

Preferably the tooth is fixed to the cutterhead on a spigot, a spigot pin extending through the tooth and the spigot to secure it thereon. Alternatively, the tooth can be fitted on a spigot with a spiral form, with a spigot pin being fitted at a side of the spigot and tooth, to

prevent the tooth from turning off the spiral form. Alternatively, the tooth may be tack-welded or glued onto a spigot of the cutterhead. The cuttertooth manipulator, therefore, comprises a hand for gripping the tooth and either a pin driver for extracting the spigot pin or a means for disconnecting the weld or glue between the tooth and the spigot, such as a weld cutter or glue solvent.

Preferably the manipulator comprises two robotic tooth handlers. The first removes worn teeth and the second fits new teeth to replace the worn teeth.

Preferably the hand is fitted to the first robotic tooth handler.

A second hand for gripping a new tooth and for securing the new tooth to a spigot may also be provided. Preferably the securement is with a spigot pin, for example by driving a spigot pin either through the tooth and the spigot or between a flange of the tooth and the side of the spigot, perhaps in a groove therein. The securement may alternatively be by welding or gluing the tooth to the spigot. The spigot preferably comprises a spiral element for assisting in the correct alignment of the tooth on the spigot. Preferably the spiral element is a quarter-turn helical thread.

The second hand is preferably provided on a second robotic tooth handler.

Preferably the manipulator is mounted on a cutterplatform of a dredger ship. Preferably the two robotic tooth handlers are mounted on opposed sides of the cutterplatform, for the cutterhead to be hoisted into a position between the two robotic tooth handlers.

Preferably the manipulator is mounted on dampers to isolate the manipulator from vibrations caused during dredging operations. Preferably the dampers can be clamped to prevent damping for when the manipulator is manipulating teeth.

Preferably the or each robotic tooth handler comprises a multi-axis robotic arm having a hand for engaging or gripping a cutterhead tooth. Preferably the hand is at the end of the arm.

Preferably motors or hydraulic systems drive the various elements of the or each multi-axis robotic arm.

A method of manipulating cutterteeth on a dredger cutterhead is also disclosed.

In a preferred aspect of the invention, there is provided a dredger cuttertooth manipulator comprising two robotic tooth handlers for removing a worn tooth from a dredger cutterhead and for replacing the removed tooth (10) with a new tooth (48). The manipulator is fitted to a dredger ship, the two robotic tooth handlers being mounted on opposed sides of a cutterplatform of the dredger ship for the cutterhead to be hoisted into a position between the two robotic tooth handlers.

Further preferred features of the present invention are set out in the claims appended hereto and will now be described, purely by way of example, with reference to the accompanying drawings in which:

Figure 1 shows a dredger ship having a cutterhead engaged with a seabed;

Figure 2 shows a preferred embodiment of a dredger cuttertooth manipulator in accordance with the present invention on a cutterplatform of the dredger ship of figure 1;

Figure 3 shows a detail of the first station of the manipulator of figure 2;

Figure 4 shows a detail of the cutterhead of the dredger ship from figure 2;

Figure 5 shows details of the second station of the manipulator of figure 2;

Figure 6 shows in plan a manipulator in accordance with the present invention;

Figure 7 shows in elevation a manipulator in accordance with the present invention;

Figure 8 shows a spigot with three alternative teeth for mounting to the spigot;

Figure 9 shows an alternative cutterhead;

Figure 10 shows a man operating a spigot pin removal tool for removing a spigot pin from a tooth and spigot in accordance with a prior art method of tooth removal; and

Figure 11 shows two men about to start to remove the spigot pin of figure 10.

Referring first to figures 9 and 10, the method of changing a tooth in accordance with the prior art will be described. A worn tooth 10 provided on a spigot 12 is shown in both figures 10 and 11.

The tooth 10 is attached to the leading edge of an arm of a cutterhead on a spigot 12 with a spigot pin 14 holding the tooth 10 in place on the spigot 12. This can more clearly be seen in figure 4 or 9. A first person 16 holds a first finger of a tooth removal tool 18 against the spigot pin 14. A second person 20 then uses a sledgehammer 22 to drive the spigot pin 14 with the tool 18 part way out of the tooth 10 and spigot 12. The tool 18 is then rotated so that a second, longer, finger 15 of the tool 18 can be used to drive the spigot pin fully out of the hole. The two step procedure is required due to the length of the pin – a shorter finger of the tool 18 will be more easy to align with the head of the spigot pin 14 when starting to drive the pin 14 from the tooth 10 and spigot 12.

A third person (not shown) then removes the old tooth 10 and replaces it with a new tooth 48 (not shown). Then the first person 16 places a new spigot pin (or the old spigot pin 14) in the tooth ready for the second person 20 to drive it through holes in the new tooth 48 and the spigot 12 for retaining the new tooth 48 on the spigot 12.

Referring now to figure 1, a dredger ship 24 is shown. The dredger ship 24 comprises a cutterladder 26 having a ladder raising and lowering wires 28 which, when pulled into the ship 24 by a pulley (not shown), raises the cutterladder 26 towards a cutterplatform 32, as shown by the arrow 30. The raised position for the cutterladder 26 is shown in dotted lines 34 in figure 1.

The cutterladder 26 has a cutterhead 36 at a distal end thereof. The cutterhead 36, in use, engages the seabed 38 for dredging material from the seabed 38.

In the raised position 34, the cutterhead 36 is clear of the surface 40 of the water. Therefore, the tooth change operation is carried out on board the ship 24.

The cutterhead 36 is shown in more detail in figures 2, 4, 6, 7 and 9. As can be seen, the cutterhead 36 is generally hemispherical and comprises coiled arms extending generally radially from the apex of the hemisphere towards the outermost rim of the hemisphere. However, they are twisted (i.e. coiled) around the hemisphere to define a slight corkscrew. The arms are recessed or angled to provide a leading cutting edge 44 having tooth-mounting positions 46 equally spaced therealong. In the embodiment shown in figure 2 and 4, there are eight positions per leading edge 44. This provides for a total of 48 teeth. Vents or openings 42 are provided between the arms.

Referring to figure 2, one new tooth 48 is shown fitted to the Cutterhead 36. The tooth 48 is mounted on a spigot similar to the four spigots 12 shown also in figure 2. Referring to figure 4, the tooth 34 and the spigots 12 are shown more clearly. The spigots 12 are attached to, or will be formed integrally with, the tooth mounting positions 46 provided on the cutterhead 36.

As shown in figure 9, additional teeth 50 can be provided around the outermost circumference of the cutterhead 36. With these additional teeth 50, the total number of teeth on the cutterhead is increased to 54.

More than eight tooth-mounting positions 46 can be provided on the leading edges 44 of the arms. Further, more than six arms could be provided. Similarly, less teeth can be provided on each leading edge or fewer than six arms can be provided. For the purpose of this specific description, however, only 48 teeth 48 are provided on the cutterhead 36.

Referring to figure 11, a detail of a preferred connection between a tooth 10 and the spigot 12 is shown. The tooth 10 is shown as a worn tooth. In order to attach the tooth 10 to the spigot 12, the tooth 10, which has an aperture (not shown) in its base, sized to fit snugly

over the spigot 12 (shown in full in figure 4), is fitted over the spigot 12 so that holes 52 (one shown) in the tooth 10 align with a hole (not shown) in the spigot 12. The holes 52 in the tooth 10 are provided in flanges 54 extending from the base that engage in a slot provided in the spigots 12. This helps to prevent rotation or malalignment of the tooth on the spigot 12 since the flanges locate in the slots. A spigot pin 14 is then driven through the holes to lock the tooth 10 in place on the spigot 12. The pin locks in the holes with an engagement fit in both the opposed holes 52 of the tooth 10 and the hole in the spigot 12. The engagement fit is sufficient to prevent inadvertent removal of the pin in use. Other methods of attachment are, however, possible, as would be readily apparent to a skilled person, or as also used in the field of dredger cutterheads.

Figure 8 shows an alternative arrangement for the spigot 12. The spigot 12 itself is square in section across its axis but spiralled along its axis. The spigot 12, therefore, has a spiral form – a quarter-turn helical thread.

Three different teeth 48 are also shown, with different point shapes. There is a pick point 110, a flared point 112 and a chisel point 114. These each are suitable for different rock types.

The teeth 48 and the spigot 12 shown in Figure 8 are generally in accordance with spigots 12 and teeth 48 that can be obtained from Esco (RTM) under the trademark Heliloc (RTM), which teeth are well known in the art of dredging. The teeth (only one of which will be fitted to each spigot) have an aperture (not shown) at their bases 116 similarly shaped to the spigot for fitting onto and mating with the helical thread of the spigot 12.

In the installed position (not shown), the flange 117 of the tooth 48 will oppose a flat 115 of the spigot 12. A spigot pin 14, in the form of a slip of metal, rather than a cylindrical member, will then fit tightly into the gap between the flange 117 and the flat 115 to secure the tooth 48 onto the spigot 12. The pin 14, therefore, in use is fitted at a side of the spigot and against the flange 117 of the tooth 48 to prevent the tooth 48 from turning off the spiral form of the spigot 12.

The pin 14 can later be removed from the spigot and tooth arrangement by driving its bottom face (not shown). This allows the tooth 48 to be removed from the spigot 12.

In another arrangement, not shown, the tooth may be tack welded (or otherwise welded) to a spigot. The pin 14 would then not be required. Alternatively, the tooth may be glued onto a spigot. Suitable glues include high-impact epoxy, which can be pre-applied to the inside of the aperture of the tooth. The Exco Spherilok (RTM) system, as well known in the art of dredging, is particularly suitable in this regard. Further, the Esco Quadrilok (RTM) system, also well known in the art of dredging, is also particularly useful.

Depending upon the form of connection between the tooth 48 and the spigot 12, the hand or hands of the cuttertooth manipulator, therefore, comprises a hand for gripping the tooth and either a pin driver for fitting/extracting the spigot pin, or a means for welding or disconnecting the weld, or a means for gluing/disconnecting the glue between the tooth and the spigot, such as a welder/weld cutter or a gluing means and glue solvent dispensing means. If the tooth, however, has glue pre-applied to the aperture, such as is the case with Esco spherilok (RTM) teeth, then the gluing means (or a glue applier) will not be required.

The manipulator of the invention will be described for an embodiment for replacing teeth of the type secured with a pin extending through both the tooth and the spigot. A skilled person will, however, readily appreciate that the hand or hands can be appropriately adapted to suit the various different types of tooth connection that exist in the art.

In accordance with the present invention, instead of manually changing these teeth, as done in the prior art, a dredger cuttertooth manipulator or robotic tooth-handling device is provided. As shown in figure 2, the manipulator comprises two stations. The first station, the tooth removal station 56, is shown on the left hand side of figure 2 and in figure 3. The second station, the new tooth fitting station 58, is shown on the right hand side of figure 2 and in figure 5.

The cutterhead 36 during cuttertooth manipulation (i.e. during the tooth change procedure) is raised to the cutterplatform 32, as in the prior art, and as shown in the drawings. However, with the present invention, the cutterhead 36, although being raised to the same

position on the cutterplatform 32, is now positioned between the two stations 56, 58, rather than up to personnel on the cutterplatform 32, i.e. the personnel are now replaced by the manipulator of the present invention.

Referring now to figure 3, the tooth removal station 56 comprises a waste bin 60 comprising two compartments 94, 96, a safety barrier 62 and a robotic tooth handler 64. The waste bin 60 is positioned on the opposite side of the robotic tooth handler 54 to the cutterhead 36. The safety barrier 62 is positioned between the waste bin 60 and the robotic tooth handler 64 to cover power lines such as electric, hydraulic or pneumatic cabling or pipes that go to the robotic tooth handler 64.

Instead of a waste bin, an array, for example for receiving worn teeth, can be provided. This would enable the worn teeth to be more easily handled after removal. See the description below with regard to the second station 58, for an example of a suitable type of array.

The robotic tooth handler 64 is a multi-axis robot with an arm and a hand for handling a tooth on the cutterhead 36. Multi-axis control is provided since the various teeth on the cutterhead do not have parallel axes. Further, the axis of each tooth relative to the robotic tooth handler is variable since the cutterhead is rotatable. The robotic tooth handler 64, therefore, due to the multi-axis control, is able to manoeuvre its arm and hand to position the hand not only in the right position but also at the right orientation to grasp and manipulate the various teeth 10, one at a time.

The robotic tooth handler 64 sits upon a table top 66. The table top 66 has sliding stops 68 towards each end thereof. The robotic tooth handler 64 can be made to slide or move on the table top 66 by pulleys, a belt or a toothrack (not shown). This allows the robotic tooth handler 64 to be moved along a line parallel to the axis of the cutterhead 38 for assisting in the positioning of the hand relative to each tooth along the leading edge 44 of an arm.

The handler is mounted on vibration dampers that are active when the system is not in use. This protects the equipment during dredging operations; vibrations will be transmitted along the ladder to the cutterplatform from the cutterhead during dredging operations. The

dampers prevent the manipulator from being damaged during dredging operations. However, when the manipulator is in use and the cutterhead is positioned between the two stations 56, 58, accuracy is required for the manipulation of the teeth. Therefore, clamps (not shown), for example driven by hydraulic cylinders, clamp down the dampers so that there can be no movement of the manipulators other than the movement required in order for manipulation of the teeth.

On the base 70 of the robotic tooth handler 64, a turntable 73 is provided. This allows the robotic tooth handler 64 to be rotated about a vertical or first axis that is substantially perpendicular to the central axis of the cutterhead 36 when the cutterhead 36 is in its lifted or hoisted position at the cutterplatform 32. The rotation is driven by a motor. However, as with all the moving parts of the robot, rotation or swinging of the handler may be caused by other means well known to persons skilled in the art, such as by belts, gears or pneumatic or hydraulic means.

Above the turntable, the robotic tooth handler 64 comprises multiple, linearly interconnected, swingable arm sections. They are effectively joined end to end, terminating in a hand 90, much like a conventional robotic arm. A first arm section 72 can be rotated about an axle 74 that is mounted on a base bracket 76 of the robotic tooth handler 64. This first arm section 72 has at its uppermost end a further rotatable axle 78 which has an axis that is parallel to the first axle 74. A second arm section 80 is provided at the second axle 78. It is rotatable about a further rotatable axle 82, which axle 82 has an axis perpendicular to the first axle 74. The second arm section 80 is rotatable about its own axis around axle 82. This rotation is driven by a motor 84.

The second arm section 80 has an elbow 86 and a wrist 88 to allow precise multi-axis manipulation of the hand 90. The hand 90 is mounted at the end of the second arm section 80. The hand 90 comprises a tooth grasping mechanism and a spigot pin removing mechanism, such as a hydraulic driver. It also includes a spigot pin grasping mechanism for grasping spigot pins upon removing them from the tooth and spigot assembly.

Precise details of the hand and arm elements and their control systems are not provided; a skilled person in the art of robotics and manipulators will readily appreciate the potential

constructional details of the many possible incarnations of such a multi-axis arm and hand. The arms and hands of the manipulator of the present invention must be designed to be strong enough, however, to be capable of handling the forces required to manipulate the teeth off and onto the cutterhead.

Many multi-axis robotic arm designs other than that shown in the drawings could achieve this result, as would as be apparent to a person skilled in the art of robotics. However, there are preferably provided six axes of movement, with a seventh axis of movement also being provided by the sliding of the handler along the tabletop.

In figure 3, a tooth 10 is shown grasped by the hand 90. The multi-axis robotic tooth handler 64 is also shown to be swinging towards the waste bin 60, as shown by arrow 92. Upon swinging the hand 90 over the waste bin 60, the tooth 10 is dropped into a first compartment of 94 of the waste bin 60. The arm continues to swing and the spigot pin (not shown) is then dropped into a second compartment 96 of the waste bin 60. The spigot pin can generally be reused without reprocessing. However, the teeth 10, since they are worn, will need to be reprocessed before they can be used again. It is for this reason that the two items are sorted in this manner.

The manipulator of the present invention has a computer control system to guide hand 90 onto a worn tooth, which will not necessarily be in a fixed position relative to the handler 64. Therefore, the hand 90 shown in the drawings is fitted with an optical tooth sensing system (not shown) to enable the computer control system to control and position the robotic tooth handler 64, its arms and the hand so as to engage and then remove any or all of the variously worn teeth, in turn. Other position sensing means can also be used, as would be well known to a person skilled in the art of robotics.

The software driving the hand positioning control system could also be programmed to recognise a worn tooth as opposed to an acceptable tooth and only replace those teeth which are worn. Image matching software can be used of this purpose, for example.

The rotation control of the cutterhead can also be connected to the computer system for the robotic tooth handler 64. The cutterhead can then be rotated incrementally to move the

leading edge 44, and therefore the teeth 10, to an appropriate rotational position for the teeth thereon to be handled by the robotic tooth handler 64 more easily, or in a stepwise manner.

On the opposite side of the cutterhead 38, a second robotic tooth handler 98 is provided. As with the first robotic tooth handler 64, the second robotic tooth handler 98 is a multi-axis device. It has a base 100 mounted on a tabletop 102 having stops 104 (see figure 6) at each end thereof so that the robotic tooth handler 98 can be moved on the tabletop 102 parallel to the axis of the cutterhead 38. Further, the robotic tooth handler 98 has rotateable or swingable arms sections and various axles and motors for driving the swinging or rotating sections. These arm sections and axles are generally the same as or similar to the first robotic tooth handler 64. However, the hand on the second robotic tooth handler 98, although generally similar in design, is for positioning a new tooth 48 onto the spigots 12 that have had a worn teeth 10 removed therefrom by the first robotic tooth handler 64.

The computer control for the second robotic tooth handler 98 is linked to the computer control for the first robotic tooth handler 64 to instruct it as to which location to fit a new tooth.

Again an optical position control system may be provided for the hand of the second robotic tooth handler 98. It will guide the hand for fitting new teeth or for picking up a new tooth from a supply of teeth. The optical control system may in addition be used to identify spigots without a tooth. This could work either with or separate to the connection linking the two computer controls together. It would in particular allow the replacement of teeth that fell off spigots at the seabed.

A significant difference between the second robotic tooth handler 98 and the first robotic tooth handler 64 is that instead of a waste bin 60, an array of new teeth 48 is provided. The array of new teeth 48 are positioned on tooth benches 106 that extend parallel to the axis of the cutterhead 38. Three such tooth benches 106 are provided, each provided at a different height. This staggered effect enables the hand of the second robotic tooth handler 98 to

grasp teeth 48 from the different benches 106 more easily since the teeth 48 on other benches 106 will not interfere with the movement of the handler 98.

The teeth are positioned point up so that the hand of the tooth handler 98 will be able to position the aperture of the underside of the tooth over the spigot 12 of the cutterhead 38 without adjusting its grip on the tooth 48.

At an end of the tabletop 102 there are provided spigot pin magazine dispensers 108. The dispensers 108 contain small containers containing a number of new (or recycled) spigot pins 14. The containers, and the dispensers 108, operate in much the same manner as a magazine of a machinegun or rifle. In addition to collecting a tooth 48 from the tooth benches 106, the hand of the second robotic tooth handler 98, as and when required, will collect a spigot pin magazine from one of the dispensers 108. The pins 14 in the magazine will them be used for fastening the new tooth 48 to the spigot 12 of the cutterhead 38. A spigot pin grasping mechanism and hydraulic driver (not shown) is provided for the hand for holding and driving the pin 14 through the tooth and spigot for attaching the new tooth 48 to the spigot 12.

Use of the present invention on a cutterplatform removes personnel from the dangerous environment of the cutterplatform. This improves safety onboard the dredger ship. Further, the robotic system is able to operate more quickly than personnel are. Yet further, the manipulator can be designed to handle teeth having a greater mass than 20kg, therefore allowing larger cutterheads to be designed and fitted to dredger ships. Yet further, the present invention enables the automation of tooth change procedures without any need to alter the design of the cutterhead or cutterladder. Further, the present invention can be retrofitted to existing cutterplatforms.

The present invention as been described above purely by way of example. Modifications in detail may be made to the invention within the scope of the claims appended hereto.